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STUDY BY THE STAFF OF THE U.S.

General Accounting Office

Issues Concerning The Department Of Defense's Global Positioning System As It Enters Production

The Department of Defense's Global Positioning System is a $3.9 billion space-based navigation system designed to provide worldwide position information in 3 dimensions, together with velocity and time information, for a multiplicity of military and civil users.

As the system's space segment enters production on a multiyear contract basis, remaining technical and program risks could adversely affect the stability of spacecraft design, achievement of full operational capability by September 1988, and overall program costs. Also, the current multiyear procurement cost estimate associated with the space segment is uncertain because it is not based on a firm price proposal, and associated savings are overstated because they were not calculated using an acceptable method.

Efforts to offset the high cost of the Global Positioning System by phasing out existing navigational systems and by charging fees to non-Defense users are not likely to materialize as planned.

GAO/MASAD-83-9
JANUARY 26, 1983

PREFACE

At the request of the Chairman, Senate Subcommittee on Defense Appropriations, we conducted a study of the Department of Defense's Global Positioning System (GPS). Our objectives were to examine the reasonableness of the multiyear procurement strategy proposed for the space segment of the system and determine the status of the system's design and likely operational capabilities. We also inquired about the user segment of the program and plans to phase out certain existing navigational systems.

On April 23, 1982, and July 1, 1982, we briefed subcommittee staff on issues that we had then identified. This study represents our latest assessment of those issues and can serve as a basis for the Congress to monitor the GPS program and for us to conduct future work.

Chapter 1 briefly describes the GPS program. Chapter 2 discusses Defense's multiyear procurement strategy and the associated cost uncertainties. Chapter 3 presents information on technical and program risks that deserve close monitoring. Chapter 4 describes the problems likely to be encountered in plans to offset GPS' high costs.

At the Chairman's request, we did not take the additional time needed to obtain agency comments on the matters discussed in this study. We did, however, discuss the sections on multiyear procurement strategy and technical and program risks with GPS program officials, and their comments have been considered in completing the study.

Questions regarding the content of this study or our plans for future work should be directed to Mr. Homer Thomson, Group Director for strategic command, control, and communications on (202) 275-8548.

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Director, Mission Analysis and
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SUMMARY

The Global Positioning System (GPS) is a space-based radio navigation system under development by the Air Force. It is designed to provide position information in 3 dimensions (longitude, latitude, and altitude), together with time and velocity information, for a multiplicity of military and civil users.

GPS consists of three major segments--the space segment, ground control segment, and user equipment segment. The space segment includes a navigation package, an integrated operational nuclear detonation detection system, and an upper stage booster for each spacecraft. To be fully operational, this segment requires 18 satellites in 6 orbital planes 10,900 nautical miles above the earth. The ground control segment consists of a master control station, three ground antenna stations, and five monitor stations to maintain control and accuracy of the spacecraft. The user segment consists of various types of receiving and processing terminals for a variety of vehicles.

The estimated cost to develop and procure GPS is $3.9 billion which includes $2.5 billion for the space segment, $440 million for the ground control segment, and $935 million for the Air Force portion of the user segment.

The Air Force intends to award a sole-source, multiyear procurement contract on a fixed price incentive basis with the Rockwell International Corporation in March 1983 for 28 production spacecraft. In September 1980, the Air Force entered into a firm fixed-price contract with the International Business Machines Corporation to develop the ground control segment. The Department of Defense (DOD) plans to make a production decision on user equipment in May 1984, with approximately 20,350 terminals projected to be procured.

MULTIYEAR PROCUREMENT STRATEGY

Our study of the multiyear procurement strategy for GPS disclosed that estimated procurement costs are uncertain and the associated savings, relative to an annual procurement strategy, are overstated.

The current cost estimate for 28 production spacecraft was based on budgetary estimates rather than contractor firm price proposals. There are also indications that the prime contractor will propose a higher cost to the government than

the multiyear procurement estimate of $1.4 billion. Also, DOD's projected savings through the use of a multiyear procurement contract were not calculated in accordance with Office of Management and Budget Circular A-94. Consequently, any savings are likely to be less than DOD has reported, primarily because planned outlays were not discounted using the present value analysis method.

TECHNICAL AND PROGRAM RISKS REMAIN

As the space segment of GPS enters production, technical and programmatic risks remain that could affect the stability of spacecraft design and the achievement of final operational capability by September 1988.

There is considerable concurrency between development and production--a risk that could result in design changes. For example, overall spacecraft integration testing, using a development qualification test vehicle, is scheduled to be conducted between 8 and 19 months after the plannned production contract award date of February 1983. Program officials acknowledge that such a risk exists, but are optimistic that the spacecraft design is sufficiently stable to proceed into production.

System design changes are already being considered that will add considerable cost to the program if fully implemented. These changes include an additional sensor to the integrated operation nuclear detonation detection system and enhancements related to GPS survivability.

Finally, full operational capability of GPS by the scheduled date of September 1988 could be delayed because it is questionable whether a sufficient number of satellites will be on-orbit by that time. This is based upon an Air Force analysis that calls for 24 spacecraft to ensure an 18-satellite constellation with a 98-percent availability. The current spacecraft launch schedule shows that by September 1988 only 19 would be launched. This is five spacecraft short of the desired number determined by the Air Force to ensure that the constellation is established. Also, GPS' full operational capability is dependent upon the availability of the Space Shuttle to launch the spacecraft. GPS program officials have expressed concern that Space Shuttle uncertainties could lead to problems in meeting GPS launch requirements. No backup launch vehicles have been designated for GPS because the navigation system is not considered critical enough to warrant them.

ESTIMATED OFFSETS TO GPS COSTS ARE QUESTIONABLE

In response to congressional concern over the high cost of GPS, DOD has explained to the Congress that a large portion of GPS costs would be offset by phasing out certain existing navigation systems and by charging fees to non-DOD users.

The planned phase-out of 11 existing navigation systems is optimistic considering possible slippage in the GPS space segment final operational capability schedule; problems with development, procurement, and installation of user equipment; and the possible continued need for DOD's Tactical Air Navigation System in order for military aircraft to fly in controlled national airspace. Also, DOD's estimated annual cost avoidance of $153.5 million resulting from the phase-out is questionable.

Even with a suitable operational space segment, the phase-out depends upon the availability of user equipment and the installation of the user sets on new and existing platforms. We estimate that about 1,529 user sets would be installed by September 1988, which is less than one-third the number estimated by the Air Force.

The potential revenue from non-DOD users of GPS is uncertain to a large degree because the number of these users is unknown. Preliminary indications are that GPS, as currently being implemented, is unacceptable to civil aviation users who, according to DOD, would comprise approximately 75 percent of the non-DOD user market. Federal Aviation Administration certification would be required for GPS use as the primary single navigation system. According to the Federal Aviation Administration, at least a 24-satellite constellation would be required to provide adequate satellite geometry, coverage, and reliability.

Many policy and operational issues remain to be addressed in developing a plan for recouping GPS costs from non-DOD users.

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The above issues are discussed in more detail in the text of this staff study.

Contents

ABBREVIATIONS

DOD	Department of Defense
FAA	Federal Aviation Administration
GAO	General Accounting Ofice
GPS	Global Positioning System
IONDS	integrated operational nuclear detonation detection system
OMB	Office of Management and Budget

CHAPTER 1

INTRODUCTION

The Global Positioning System (GPS) is a space-based radio navigation system under development by the Air Force. It is designed to provide worldwide position information in 3 dimensions (longitude, latitude, and altitude), together with time and velocity information, for a multiplicity of military and civil users.

GPS, frequently referred to as NAVSTAR, has been under development since December 1973. It consists of three major segments--the space segment, ground control segment, and user segment. The space segment includes a navigational package, an integrated operational nuclear detonation detection system (IONDS), and an upper stage booster for each spacecraft. To be fully operational, GPS will require 18 satellites in 6 orbital planes 10,900 nautical miles above the earth.

The ground control segment consists of a master control station, three ground antenna stations, and five monitor stations to maintain control and accuracy of the spacecraft. These stations will be located in various parts of the world.

The user segment consists of three classes of receiving and processing equipment sets for a variety of vehicles. For example, high performance user sets are intended to be installed aboard selected tactical and strategic aircraft and submarines. Medium performance sets are to be used aboard helicopters, transport aircraft, and surface ships. Low performance user sets are being designed for trucks, tanks, and personnel.

Additional details regarding major GPS operational characteristics as currently planned, versus those established when the program entered full-scale engineering development in August 1979, and the key contractors for each of the GPS segments are shown in appendix I.

The Air Force reports that through fiscal year 1988, the total estimated cost to develop and procure GPS is $3.9 billion. This includes $2.5 billion for the space segment (which consists of 12 research and development spacecraft and 28 production spacecraft), $440 million for the ground control segment, and $935 million for the Air Force portion of the user segment which includes IONDS terminals, as well as GPS user equipment. The user segment costs do not include Army and Navy development or procurement nor do they include installation for any of the user equipment.

The Air Force intends to enter into a sole-source, multiyear procurement contract on a firm fixed price basis with the

Rockwell International Corporation in March 1983 for the 28 production spacecraft. This quantity provides for 18 operational satellites, 3 on-orbit spares to ensure that minimum navigational coverage is maintained, 3 backup spacecraft in case of launch failures, and 4 replenishment spacecraft during the first year after the final operational capability date scheduled for September 1988.

In September 1980, the Air Force entered into a firm fixed-price contract with the International Business Machines Corporation to develop the ground control segment. The scheduled final operational capability date for this segment is November 1987. The Department of Defense (DOD) plans to make a production decision on the user equipment in May 1984. Currently, it intends to procure 20,350 terminals for Army, Navy, Air Force, and Defense Mapping Agency users. DOD's long-range plans are that several existing navigation systems could be phased-out once GPS is deployed and user equipment is installed.

OBJECTIVES, SCOPE, AND METHODOLOGY

Our objectives were to examine the reasonableness of DOD's multiyear procurement strategy for the space segment of GPS, including estimated costs and projected savings, and determine the status of the system's design and likely operational capabilities. Also, we inquired about the status of the user segment and of DOD's plans to phase out certain existing navigational systems as GPS becomes fully operational. We did not conduct a comprehensive study of the GPS program nor did we examine the progress being made in developing the ground control segment. We have conducted several prior reviews of GPS and related navigation systems, and the reports are listed in appendix II.

Our work was performed primarily at the Air Force's Space Division, located in El Segundo, California, where we analyzed documents supporting the proposed multiyear award and status of design and interviewed officials of the GPS program office. We also interviewed officials within the Office of the Secretary of Defense; Headquarters, Air Force; and the Air Force Test and Evaluation Center at Kirtland Air Force Base, New Mexico. In addition, we discussed potential issues regarding civil aviation use of GPS with Federal Aviation Administration (FAA) officials responsible for radio navigation planning. We performed our study in accordance with generally accepted government auditing standards.

CHAPTER 2

MULTIYEAR PROCUREMENT STRATEGY

Our study of the Air Force's justification for proposing GPS procurement of the space segment on a multiyear basis disclosed that the estimated procurement costs are uncertain and the projected savings associated with this procurement strategy are overstated. Thus, the degree of cost confidence--a criterion for awarding a multiyear contract under Public Law 97-86--has not been demonstrated. Nor has the spacecraft's design been sufficiently stabilized--another multiyear procurement criterion--the risks of which are discussed in chapter 3. Other criteria, namely benefit to the government, stability of requirements, and stability of funding are discussed below.

On May 28, 1982, the Air Force released its request for proposal for a multiyear contract to procure 28 GPS spacecraft. In anticipation of this release, DOD provided the Congress with budget information on May 12, 1982, describing a multiyear versus an annual procurement strategy. The multiyear approach showed an estimated cost of $1,343.3 million or a projected savings of $276.7 million, compared to the Air Force's estimated cost of $1,620.0 million based on six annual contracts.

On June 21, 1982, as a result of congressional concern that the proposed multiyear plan was not fully funded and did not ensure deliveries of completed spacecraft, DOD provided the Congress with a revised multiyear plan that increased the procurement cost estimate by $64.5 million to a total of $1,407.8 million. This revision reduced projected savings by a like amount to $212.2 million, but it accelerated planned spacecraft deliveries. Details of these two funding plans are shown in appendix III. The spacecraft delivery and launch schedules are shown in appendix IV.

In late June 1982, several congressional committees approved an Air Force reprogramming request of $20.1 million for fiscal year 1982 to procure long-lead items and aerospace support to initiate the multiyear procurement strategy. As a result of this congressional approval, the Air Force awarded a long-lead contract on September 1, 1982, with a ceiling price not to exceed $19 million. This contract is to be incorporated into the multiyear contract.

PROCUREMENT COST UNCERTAINTIES

The procurement cost estimates for the space segment were developed by the Air Force with the assistance of the proposed contractor and an independent contractor employed to do cost studies. We were unable to satisfy ourselves that these cost estimates are reasonable and representative of what it will likely

cost to procure the spacecraft on either an annual or multiyear basis. We found that:

--The costs were based on budgetary estimates rather than contractor firm price proposals.

--There are inherent risks in some of the assumptions used in determining the number of spacecraft needed to achieve the required operational capability. (See ch. 3.)

--Critical program office documentation was not available or adequate to validate the accuracy of the estimates.

The uncertainty of the cost estimate is best illustrated by the Space Division's concern that the contractor's cost proposal would exceed the multiyear procurement estimate of $1.4 billion as provided to the Congress on June 21, 1982. As a result of the Space Division concerns, the proposal due date has been delayed several times from late August 1982 to provide time for the contractor to rework parts of the proposal.

The program manager told us that some portions of the contractor's proposal are high due to use of high labor and inflation rates. In an attempt to reduce the costs of the expected proposal, Space Division officials are evaluating completed portions and discussing them with the contractor. The Space Division Commander has formally expressed his concern to the contractor about the higher costs being projected. According to program officials, the proposal was received in mid-December 1982, after we completed our review. Thus, we were unable to evaluate its contents.

SAVINGS ESTIMATE OVERSTATED

The Air Force projected that GPS cost savings would accrue over a 9-year period. Although some savings may be achieved through a multiyear buy, as contrasted to a buy in six annual contracts, the estimated savings of $212.2 million identified by the Air Force are overstated. Depending on whether savings are calculated in terms of obligational authority or outlays, the results could be from 54- to 90-percent less than the Air Force estimate, as follows:

--The budgetary savings, in terms of obligational authority, as presented to the Congress are stated in then-year dollars rather than constant dollars as required by Office of Management and Budget (OMB) Circular A-94. Therefore, the Air Force included estimated inflation as a factor in the savings. When computed in constant dollars, the estimated savings of

$212.2 million would be reduced by $114.5 million to $97.7 million over the 9-year period.

--In terms of outlays, the savings must consider the cost of money as required by OMB Circular A-94. In this case, present value analysis is used in making cost comparisons which requires that outlays be discounted. Using a discount rate of 13.9 percent, total multiyear savings of $212.2 million would be reduced by $192 million to only $20.2 million, over a 14-year period.

In using present value analysis, we selected 13.9 percent because it represents the average yield on outstanding marketable treasury obligations with remaining maturities comparable to the period of the cost comparison. Details on the decreases in savings due to converting from then-year dollars to constant dollars and from considering the cost of money are shown in appendix V.

The program office expressed some concern that the discount analysis we performed compared dissimilar programs in that the satellite delivery schedules were different. In restructuring the annual procurement funding profile to reflect the multiyear procurement delivery schedule, the program office arrived at higher procurement costs based on annual contracts and therefore greater savings on a multiyear basis. Specifically, the program office computed a budgetary savings of $344.5 million versus the $212.2 million provided to the Congress on June 21, 1982. In terms of discounted outlays, the program office's estimated savings would be $292.1 million versus the $20.2 million we computed.

While this program office analysis may match delivery schedules, it does not match the information provided to the Congress or the funding constraints in effect at that time. For example, at the time the multiyear strategy was presented to the Congress, program office funding was limited to a total of $182.8 million during fiscal years 1982 and 1983. The program office disregarded this contraint in developing their new analysis and included a total of $410 million for fiscal year 1983 in the restructured annual program. This latter amount is $227.2 million greater than the funding constraints at the time the multiyear procurement strategy was presented to the Congress.

OTHER MULTIYEAR PROCUREMENT CRITERIA

Other criteria established in Public Law 97-86 to be used in determining the merits for awarding a multiyear contract include benefit to the government, stability of requirements, and stability of funding.

The criterion regarding benefit to the government requires that the use of a multiyear contract should promote both national

security and result in reduced total costs. Because of the more accurate navigational capability it is intended to provide and the increased capability for detecting nuclear detonations, GPS should enhance national security once it becomes operational. As discussed above, although some savings may be achieved, the estimated procurement costs and associated savings are uncertain.

The GPS requirements appear to be stable in that the need for the system is likely to remain unchanged during the contract period. The basic factors in this criteria--total quantity, procurement rate, and production rate--do not appear to be erratic.

Regarding the stability of funding criterion, there appears to be a reasonable expectation that funding will be requested at a level needed to avoid contract cancellation. Our study disclosed no reason to question DOD's funding commitment to the program.

CHAPTER 3

TECHNICAL AND PROGRAM RISKS REMAIN

Our study revealed that remaining technical and program risks could affect the stability of spacecraft design and the achievement of final operational capability by September 1988. Specifically, we found that:

--Overall vehicle level integration testing will not be started until after the planned procurement contract award and will continue for 11 months, resulting in concurrency between development and production.

--System design changes are being considered to enhance the IONDS capability and GPS survivability.

--The spacecraft launch schedule and the Space Shuttle's availability could result in GPS not achieving its full operational capability when planned.

The consequences of concurrency could lead to design changes and additional costs. Also, the cost of two design changes already under consideration are not included in the multiyear procurement estimate. Additional costs will be incurred and the phase-out of certain existing navigational systems will be delayed if GPS' full operational capability is not attained on schedule.

CONCURRENCY IN DEVELOPMENT TESTING AND PRODUCTION

Overall spacecraft integration testing with the qualification test vehicle is scheduled to be conducted between October 1983 and September 1984. This program development activity is 7 to 18 months after the planned March 1983 award date of the production contract. There is cause for concern not only because of concurrency but also because of changes in the design of various subsystems from the research and development spacecraft to the production spacecraft. For example, of 58 major components, 24 (41 percent) are either modified or new. In addition, current planning indicates that of these 24 components, 15 (62 percent) will not have a qualification unit built or component level testing started until between October 1982 and June 1983--5 months before to 3 months after the production contract award. A summary of these data is presented on the following page.

	Total modified or new components	Number of components not built or tested until October 1982-June 1983
Modified components from the research and development spacecraft	10	6
Modified components from other satellite programs	6	3
New components	8	6
Total	24	15

Program officials acknowledged that concurrency and risks exist, but believe the risks are low and the design is sufficiently stable for a production start because:

--The production spacecraft design will use several identical components that evolved from the research and development spacecraft; specifically 34 of 58 major items are already qualified.

--The prime contractor and the preponderance of subcontractors (89 percent) are the same as those used in building the research and development spacecraft.

--The design is sufficiently well known to ensure that requirements will be met and changes occurring, as a result of qualification testing, will be small and can be incorporated before hardware assembly. 1/

--An independent operational utility evaluation by the Air Force Test and Evaluation Center concluded that the design would meet operational requirements.

1/The request for proposal has a clause requiring the contractor to assume responsibility for incorporating any changes resulting from qualification testing into the configuration of the production spacecraft. The contractor had not submitted a proposal, when we completed our review. Therefore, we could not determine whether the contractor intends to assume the responsibility or if the responsibility is likely to be negotiated into the contract.

--The specifications for the production spacecraft will be the same as those used on the qualification test vehicle which is being procured under the research and development contract.

Although the qualification test vehicle has not yet been fully assembled, program officials said that a critical design review held during the week of March 22, 1982, did not identify any significant design deficiencies or areas of concern. Our review of the results did not disclose any information to the contrary. However, until integrated testing is completed using the qualification test vehicle, some uncertainty regarding design stability will remain. This also creates a potential for cost increases.

SYSTEM DESIGN CHANGES UNDER CONSIDERATION

Program officials are currently considering two design changes to the production spacecraft--an additional sensor (referred to as a W-sensor) to the IONDS subsystem and enhancements related to GPS survivability. These changes will add considerable cost to the program.

W-sensor

In November 1981, the Air Force directed the inclusion of an additional sensor as part of the IONDS subsystem on the GPS spacecraft to enhance its nuclear burst detection capability. The program office is currently developing the W-sensor requirements. Although the W-sensor is not part of the multiyear procurement plans, the intentions are to integrate the sensor into the multiyear contract when feasible without disrupting the planned delivery schedule. Incorporating this sensor will require design changes to both the IONDS subsystem and to the GPS spacecraft. It will also delay the IONDS user terminal initial operational capability date by 1 year to January 1988, because fiscal year 1983 funding for development of user terminals was transferred to initiate the W-sensor development effort.

The program office estimates the W-sensor will be on 25 of the planned 28 spacecraft. The cost of the W-sensor development and procurement, as estimated by the program office, is about $100 million--$25 million for development and $75 million for procurement.

Survivability enhancements

Survivability enhancements that require design changes involve more capable communications and increased nuclear hardening. The enhanced communications, called the survivable data relay, would provide a satellite relay link between the master control station and ground antenna stations located in different

parts of the world. It would be used to update navigation and clock data of satellites not visible to the master control station. Conversely, the relay links would be used to transfer satellite command and control data received by worldwide monitoring stations to the master control station. This data relay capability is intended to increase survivability by eliminating the dependency on ground lines of communication currently being used.

According to program officials, depending on availability of funds, GPS could have these capability enhancements as early as production spacecraft number 8 or as late as spacecraft number 15. An unofficial program office estimate shows the costs for development and procurement would be about $422 million through 1988. The Air Force, however, reduced this amount to $165 million because of its intentions not to incorporate survivability enhancements into the 28 production spacecraft. The Office of the Secretary of Defense subsequently increased this amount slightly to $188 million.

FULL OPERATIONAL CAPABILITY MAY NOT BE MET WHEN PLANNED

The Air Force could very likely have difficulty in achieving its goal of a worldwide 3-dimensional navigational capability by the scheduled date of September 1988. This full operational capability requires a constellation of 18 functioning satellites. However, it is questionable whether a sufficient number of satellites will be on-orbit by that time based on the current launch schedule. Also, uncertainties associated with the Space Shuttle and the lack of backup expendable launch vehicles pose risks in achieving this capability on schedule.

Spacecraft launch schedule

The Air Force has determined that 24 satellites are needed to ensure that the desired capability will be available 98 percent of the time. This includes 18 required for minimum coverage, 3 on-orbit spares needed to maintain 98 percent availability, and 3 additional spares in case of failure during launches before the 21 satellites achieve orbit. This analysis projected satellite availability over a 15-year period and considered several factors, including satellite reliability, Space Shuttle reliability, upper stage booster reliability, launch delays, critical component mortality, constellation geometry, and production schedules.

Based on the Air Force's plan presented to the Congress in June 1982 (see app. IV), the launch schedule shows that only 19 satellites would be launched by 1988. This is 5 less than the 24 satellites determined by the Air Force to be needed to ensure a fully capable constellation, including the probability of 3 launch failures. If no launch failures occur, the 19 satellite launch

schedule would be 2 less than needed. This means that the Air Force would be taking greater risk than its own analysis calls for in meeting the operational capability date, thus full system usage could be delayed.

On October 27, 1982, GPS program representatives provided to us a study which they called a "satellite generalized availability program analysis." The study shows that the 98-percent availability will be reached by January 1989. However, our review indicated that the analysis was based on a launch schedule other than the one presently contemplated and provided to the Congress and included the use of research and development satellites in arriving at the 98-percent availability. This was confirmed by the official responsible for developing the analysis, and we were advised that a new analysis, using the more current launch schedule, was being developed.

Space Shuttle availability

The Air Force plans to have GPS operational spacecraft launched from the National Aeronautics and Space Administration's Space Shuttle beginning in January 1986. Because of uncertainties associated with the Space Shuttle and the lack of backup expendable launch vehicles (unmanned rockets), there is an additional element of risk in achieving full operational capability of the GPS space segment by September 1988.

GPS is referred to as a "launch of opportunity" spacecraft in that the spacecraft will be carried aboard the Shuttle on a space available basis. For fiscal years 1986 and 1987, all GPS spacecraft launches have been manifested on the Shuttle. Representatives of the Shuttle launch planning office do not believe that getting space on the Shuttle for launches after 1987 will be a problem.

However, GPS program officials expressed concern that the Shuttle may be unable to satisfy GPS launch requirements because of Shuttle program uncertainties that include the number of Shuttles to be funded, Shuttle turnaround time, total user demand for Shuttle manifest space, and possible problems leading to Shuttle delays or grounding of the Shuttle fleet.

In March 1982, the Air Force Test and Evaluation Center, in its operational utility evaluation report for the GPS space segment, also expressed concern that the establishment of and maintenance planning for the GPS satellite constellation assumes adequate Space Shuttle support. The report stated that this was an area of concern because Shuttle reliability, availability, and capability was not well established and that a backup launch capability may be needed.

The GPS program office does not have direction to provide a backup launch capability nor does the Air Force have a contingency plan to ensure full operational capability of the GPS space segment by 1988 if the Space Shuttle is unavailable to launch GPS spacecraft. Air Force strategy for critical DOD satellites is to maintain a limited number of Titan III (34)D expendable launch vehicles as backup to ensure a launch capability in the event problems or delays occur with the Shuttle. However, the planning office for the Titan III (34)D stated that GPS has not been designated as a critical program for backup launch vehicles.

Even if expendable launch vehicles were to be used, the Air Force would be faced with a problem associated with the accuracy of the upper stage booster. This booster, referred to as SGS-II, is used in both Titan and Atlas rockets. It has experienced a coning motion which could improperly position the satellite. Coning occurs when, upon ascent, the upper stage rocket spins unevenly due to nonuniform thrust from the rocket motor. The result of correcting the satellites position would be excessive use of onboard maneuvering fuel which would decrease expected satellite life.

Although a different upper stage booster, referred to as Payload Assist Module-Delta (PAM-D), would be used for launching GPS from the Shuttle, the booster uses the same rocket motor as the SGS-II. The PAM-D has been used successfully on seven non-GPS launches, but in doing so has experienced a coning motion that is not within an acceptable margin of error for GPS operational spacecraft. System specifications allow for an error up to 5 percent, but to date, 10 to 15 percent has been exhibited. Program officials believe that this coning motion could be compensated for by adding a mutation control system to the spacecraft if the problem cannot otherwise be overcome. Such a system would sense the coning motion and fire its own thrusters to counteract the motion.

CHAPTER 4

ESTIMATED OFFSETS TO GPS COSTS ARE QUESTIONABLE

During the past 2 years, there has been much congressional concern over the high cost of GPS. In 1980 we reported that GPS life-cycle costs could run as high as $8.6 billion. 1/ DOD has explained to the Congress that a large portion of GPS cost would be offset by phasing out certain existing navigation systems and by charging fees to non-DOD users. Our study indicates that:

--Potential problems could hinder or delay the phase-out of existing systems and DOD's estimated cost-avoidance figures associated with the phase-out are questionable.

--The degree to which revenues from non-DOD users will materialize is uncertain.

PHASE-OUT OF EXISTING NAVIGATION SYSTEMS IS OPTIMISTIC

In May 1982, DOD told the Congress that as GPS became operational it would phase out 11 existing navigation systems over the period 1987 to 1997. Our evaluation indicates that potential risks could delay or limit the phase-out of existing systems. In addition, even if the phase-out proceeds as projected, the cost avoidance estimate of approximately $153.5 million that DOD provided to the Congress is questionable.

Phase-out of existing systems as currently projected by DOD could be delayed or limited due to

--slippage in the GPS space segment final operational capability schedule;

--problems with development, procurement, and installation of user equipment; and

--the issue regarding the possible continued need for DOD's Tactical Air Navigation System (TACAN) for military aircraft to fly in controlled national airspace.

DOD does not plan to begin phasing out existing navigation systems until a suitable GPS operating capability has been attained. Although final operational capability is scheduled for

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1/"NAVSTAR Should Improve The Effectiveness Of Military Missions--Cost Has Increased" (PSAD-80-21, Feb. 15, 1980).

September 1988, such phase-out is contingent on avoiding problems associated with the technical and program risks discussed in chapter 3. This includes stabilizing the GPS design, completing satisfactory testing, and meeting spacecraft delivery and launch schedules.

Even with a suitable operational space segment, the start and length of the phase-out depends on the availability of GPS user equipment and the installation of the user sets on new and existing platforms. Installation and integration of user equipment is projected to be highly technical, complex, and expensive. Also, the availability of platforms must be closely coordinated with the availability of user equipment regarding new installations and retrofits.

In May 1982, the Air Force advised the Congress that the projected number of GPS user equipment sets to be procured was approximately 20,000. Also, the Air Force estimated that about 5,000 users would be equipped by 1988. Our study shows that the number of equipped users by September 1988 would more likely be less than one-third that amount. More specifically, the table below shows the current Air Force projected user equipment quantity, the programmed procurement through fiscal year 1988, and our estimate of likely installation by September 1988 when GPS is expected to be fully operational.

DOD agency	Projected number of users	Programmed procurement through FY 1988	Our estimate of equipment users by September 1988
Army	3,500	1,756	649
Navy	5,800	2,249	365
Air Force	11,000	1,992	515
Defense Mapping Agency	50	(a)	(a)
Total	20,350	5,997	1,529

a/Information not available.

Program officials provided us the information about the programmed procurement of 5,997 user terminals. We were advised that after awarding a procurement contract, it takes approximately 2 years to deliver and install the equipment. By using the quantities shown in the planned procurement schedule and applying the 2-year criterion, we estimated that about 1,529 user sets would

likely be installed by September 1988. This means that GPS use would evolve more slowly than anticipated.

Finally, there is also some concern that military aircraft equipped solely with GPS may be unable to fly in FAA-controlled airspace. FAA has the responsibility to provide for safe and efficient navigation and control of all civil and military aviation, except for DOD needs peculiar to air warfare. To fly in U.S. airspace, military aircraft use DOD's TACAN system. With the implementation of GPS, DOD has told the Congress that it will phase out TACAN by 1997. However, FAA assessments of potential GPS satellite outages, occasional poor geometry, and potential user equipment inaccuracies may make use of TACAN or other equipment necessary to provide for adequate navigation accuracy in the event of GPS failures. DOD, the Department of Transportation, and FAA are working to resolve this issue.

Even with a timely and effective phase-out of existing systems, DOD's cost avoidance estimate is questionable. DOD has explained to the Congress that as the phase-out begins, so will cost avoidances, eventually reaching an annual savings of $153.5 million when the phase-out is completed in 1997. The estimated $153.5 million is an average of fiscal years 1980 through 1982 appropriations for research, development, test and evaluation, and procurement, and an average of fiscal years 1979 through 1981 for operations and maintenance costs. Some of the costs during this period are one-time modernization costs which do not recur annually. For example, included in the estimate is $68 million from the phase-out of TACAN. Of that $68 million, $24 million is for procurement of new TACAN transmitters. This procurement was part of an overall modernization of the entire TACAN system which is nearing completion and which should provide adequate capability until TACAN is phased out. Thus, the $24 million is not an annual recurring cost avoidance. Also, the remaining $44 million TACAN operation and maintenance costs appear to be high. We reported in November 1981, 1/ that DOD estimated it spent approximately $19.7 million annually to operate and maintain TACAN.

1/"DOD Should Defer Buying New TACAN Equipment and Evaluate Other Alternatives" (MASAD-82-6, Nov. 12, 1981).

POTENTIAL REVENUE FROM NON-DOD USERS IS UNCERTAIN

In response to congressional requests 1/ that DOD provide a comprehensive plan for recouping GPS costs from non-DOD users, DOD completed a preliminary report which concludes that as much as $4.25 billion could be collected from non-DOD users during the 30-year period 1986 through 2016. Although there is concern as to exactly what costs should be recouped, how such a program should be administered, and the credibility of the revenue estimate, perhaps the more fundamental issue is to what degree there will be a significant number of non-DOD users from which to collect revenue. Preliminary indications are that GPS, as currently being implemented, is unacceptable to the civil aviation users who, according to DOD, would comprise approximately 75 percent of the non-DOD user market.

Although several factors affect the degree to which non-DOD users will accept and use GPS, FAA certification is perhaps the most critical issue. FAA has testified before the Congress and stated in a recent report that neither DOD's proposed 18 or 21 (18 plus 3 spares) satellite system is acceptable to civil aviation because of inadequate satellite geometry, coverage, and reliability. According to FAA, certification of GPS for civil aviation use as the primary single navigation system dictates the need for at least a 24-satellite constellation. DOD officials recently testified that GPS as currently configured is adequate for civil use and that by scaling the system down from 24 to 18 satellites there should be no impact on civilian acceptance and use of GPS. Both DOD and the Department of Transportation are addressing this issue and, by the end of 1983, will make preliminary recommendations which should further clarify the civilian acceptance and use of GPS.

Given that some type of non-DOD user market does materialize, DOD's report to the Congress recognizes that many policy and operational issues remain to be addressed in developing a comprehensive plan for recouping GPS costs from non-DOD users. A great deal more analysis needs to be accomplished before deciding if and how collecting revenue from non-DOD users could be implemented as an effective method for offsetting GPS costs.

1/Senate Report No. 97-273; Department of Defense Appropriation Bill, 1982, p. 89; House of Representatives Report No. 97-311; and Department of Defense Authorization Act, 1982, p. 90.

APPENDIX I

MAJOR OPERATIONAL CHARACTERISTICS AND KEY CONTRACTORS OF GPS

Major program operational characteristics

	1979	Current
Satellite constellation	24	18
Navigation capability:		
2-dimension (longitude and latitude)	1985 (18 satellites)	2nd quarter CY 1987 (12 satellites)
3-dimension (longitude,	1987 (24 satellites)	4th quarter CY 1988 (18 satellites)
Required average systems accuracy	10 meters	16 meters (14.6 meters predicted)
Availability: a/		
System availability -- 18-satellite constellation	98 percent	98 percent
Worldwide 3-dimension capability--at least 4 satellites in view from any point on the earth	95 percent	95 percent (99.5 percent predicted)
Outages at given points on earth		2 daily (10 minutes average duration)

a/Subject to successful launches and achievement of satellite reliability goals (design life 7.5 years, mean mission duration of 6.2 years).

APPENDIX I

Space segment	Control segment	User segment
Key contractors:		
Space contractor: Rockwell International Space Operations & Satellite Systems Division Seal Beach, California	IBM Federal System Division Gaithersburg, Maryland	Magnavox Advanced Products & Systems Co. Electronic Corp. Torrance, California
Navigation Subsystem: International Telephone and Telegraph Nutley, New Jersey		Rockwell International Avionics & Missile Group Cedar Rapids, Iowa
IONDS Subsystem: Rockwell International Collins Communications Systems Division Anaheim, California		
Rockwell International Autonetics Strategic Systems Division Anaheim, California		
Upper Stage Contractor: McDonnell Douglas Astronautics Huntington Beach, California		

APPENDIX II

OUR REPORTS ON GPS

AND OTHER RELATED NAVIGATION SYSTEMS

1. "DOD Should Defer Buying New TACAN Equipment and Evaluate Other Alternatives" (MASAD-82-6, Nov. 12, 1981).

2. "DOT Should Terminate Further LORAN-C Development and Modernization and Exploit the Potential of the NAVSTAR/ Global Positioning System" (MASAD-81-42, Sept. 18, 1981).

3. "NAVSTAR Should Improve the Effectiveness of Military Missions--Cost Has Increased" (PSAD-80-21, Feb. 15, 1980).

4. "Should NAVSTAR Be Used for Civil Navigation? FAA Should Improve Its Efforts to Decide" (LCD-79-104, Apr. 30, 1979).

5. "The NAVSTAR Global Positioning System--A Program With Many Uncertainties" (PSAD-79-16, Jan. 17, 1979).

6. "Status of the NAVSTAR Global Positioning System" (PSAD-78-37, Apr. 25, 1978).

7. "Navigation Planning--Need for a New Direction" (LCD-77-109, Mar. 21, 1978).

8. "Status of the NAVSTAR Global Positioning System" (PSAD-77-23, Mar. 2, 1977).

9. "Comparison of the NAVSTAR Program With the Acquisition Plan Recommended by the Commission on Government Procurement" (PSAD-77-50, Jan. 24, 1977).

GPS FUNDING PLANS FOR MULTIYEAR VERSUS ANNUAL PROCUREMENT

	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	TOTAL
	(millions in then-year dollars)									
Original (5/12/82) estimate of funding needs:										
Annual	$20.5	$162.3	$242.0	$374.0	$334.4	$327.9	$124.4	$ 17.5	$ 17.0	$1,620.0
Multiyear	20.5	162.3	234.1	363.2	245.4	179.8	98.5	39.5	-	1,343.3
Savings	$ -	$ -	$ 7.9	$ 10.8	$ 89.0	$148.1	$ 25.9	$(22.0)	$ 17.0	$ 276.7
Revised (6/21/82) estimate of funding needs:[a]										
Annual	$20.5	$162.3	$242.0	$374.0	$334.4	$327.9	$124.4	$ 17.5	$ 17.0	$1,620.0
Multiyear	20.5	162.3	298.6	363.2	245.4	179.8	105.1	32.9	-	1,407.8
Savings	$ -	$ -	$(56.6)	$ 10.8	$ 89.0	$148.1	$ 19.3	$(15.4)	$ 17.0	$ 212.2

[a]/Excludes: control segment; user equipment segment; Shuttle peculiar launch costs; PAM-D airborne support equipment, launch support, first time integration; IONDS government-furnished equipment; and AFESC crypto boxes.

APPENDIX III

APPENDIX IV

MULTIYEAR PROCUREMENT

PLANNED DELIVERY AND LAUNCH SCHEDULES

FOR GPS

Description	Fiscal years 1985	1986	1987	1988	Sub total	1989	1990	Total
Data supporting MYP-- presented to the Congress on 5/12/82:								
Deliveries	3	7	7	7	24	4	-	28
Launches	3	7	7	7	24	4	-	28
Cumulative on-orbit production satellites	3	9	15	21	21	-	-	-
RFP--released 5/28/82 (contract award planned for Sept./Oct. 1982): a/								
Deliveries	-	4	7	7	18	7	3	28
Launches	----Not determined by program office----							
Cumulative on-orbit production satellites	----Not determined by program office----							
Current plan--presented to the Congress 6/21/82 (contract/award planned for August 82): a,b/								
Deliveries	3	7	7	6	23	5	-	28
Launches	1 c/	4	7	7	19	7	2	28
Cumulative on-orbit production satellites	----Not determined by program office----							

a/Contract award is now planned for March 1983.

b/On September 1, 1982, a contract for long-lead items was awarded. This long-lead contract is planned to be superseded and incorporated into the multiyear contract when awarded in March 1983.

c/First production spacecraft launch is now scheduled for January 1986.

COMPARISON OF ESTIMATED SAVINGS BASED ON CONSTANT DOLLARS, OUTLAY STREAMS, AND DISCOUNTED OUTLAYS

Budgetary savings:	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90	Sub total	FY 91	FY 92	FY 93	FY 94	FY 95	Total
	(millions)															
Then-year dollars	$ -	$ -	$ (56.6)	$ 10.8	$ 89.0	$148.1	$ 19.3	$(15.4)	$17.0	$ 212.2	-	-	-	-	-	$ 212.2
Constant 1979 dollars	-	-	(32.8)	5.5	45.3	70.8	8.7	(6.5)	6.7	97.7	-	-	-	-	-	97.7
Escalation	$ -	$ -	$ (23.8)	$ 5.3	$ 43.7	$ 77.3	$ 10.6	$ (8.9)	$ 10.3	$ 114.5	-	-	-	-	-	$ 114.5
Outlays:[a]																
(Then-year dollars)																
Annual	$ 1.5	$ 23.5	$ 109.1	$198.0	$292.8	$323.3	$306.6	$202.0	$ 95.1	$1,551.9	$43.9	$17.9	$4.8	$1.2	$0.3	$1,620.0
Multiyear	9.9	154.9	225.2	183.0	168.9	140.8	211.2	239.3	74.6	1,407.8	-	-	-	-	-	1,407.8
Savings	$(8.4)	$(131.4)	$(116.1)	$ 15.0	$123.9	$182.5	$ 95.4	$(37.3)	$ 20.5	$ 144.1	$43.9	$17.9	$4.8	$1.2	$0.3	$ 212.2
Discounted outlays:[b]																
Annual	$ 1.4	$ 19.3	$ 78.8	$125.6	$163.0	$158.0	$131.5	$ 76.1	$ 31.5	$ 785.2	$12.7	$ 4.6	$1.1	$0.2	$0.1	$ 803.9
Multiyear	9.3	127.4	162.7	116.0	94.0	68.8	90.6	90.2	24.7	783.7	-	-	-	-	-	783.7
Savings	$(7.9)	$(108.1)	$(83.9)	$ 9.6	$ 69.0	$ 89.2	$ 40.9	$(14.1)	$ 6.8	$ 1.5	$12.7	$ 4.6	$1.1	$0.2	$0.1	$ 20.2

[a]/Annual outlays based on the January 1982 Office of the Secretary of Defense expenditure indixes; multiyear outlays based on contractor developed historical expenditure curves.

[b]/Present value using a discount rate of 13.9 percent--the average yield rate on outstanding marketable treasury obligations with remaining maturities comparable to the period of the analysis.

APPENDIX V

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